Influential publications in ecological economics revisited

Robert Costanza, Richard B. Howarth, Ida Kubiszewski, Shuang Liu, Chunbo Ma, Gaël Plumecocq, David I. Stern

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Robert Costanza
Crawford School of Public Policy, The Australian National University, Acton, ACT 2601, Australia.

Richard B. Howarth
Environmental Studies Program, Dartmouth College, Hanover, NH 03755, USA.

Ida Kubiszewski
Crawford School of Public Policy, The Australian National University, Acton, ACT 2601, Australia.

Shuang Liu
Land and Water Flagship, CSIRO, Canberra, ACT 2601, Australia.

Chunbo Ma
School of Agricultural and Resource Economics, University of Western Australia, Perth, WA 6009, Australia.

Gaël Plumecocq
INRA, UMR 1248 Agir, BP 52627. F- 31326 Castanet-TolosanCedex, France.

David I. Stern
Crawford School of Public Policy, The Australian National University, Acton, ACT 2601, Australia.
Corresponding author: david.stern@anu.edu.au

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Abstract

We revisit the analysis of Costanza*et al*. (2004, *Ecological Economics*) of influential publications in ecological economics to discover what has changed a decade on. We examine which sources have been influential on the field of ecological economics in the past decade, which articles in the journal *Ecological Economics* have had the most influence on the field and on the rest of science, and on which areas of science the journal is having the most influence. We find that the field has matured over this period, with articles published in the journal having a greater influence than before, an increase in citation links to environmental studies journals, a reduction in citation links to mainstream economics journals, and possibly a shift in themes to a more applied and empirical direction.

Keywords: Bibliometrics, ecological economics

JEL Codes: A12, A14, Q57

1. Introduction

Ecological economics is a transdisciplinary field of study.It is influenced by and has influence on a broad range of disciplines and topics. We revisit the analysis of Costanza *et al*. (2004) of influential publications in ecological economics to discover what has changed a decade on. We compare our findings with this previous work to determine how the journal and the field have changed in the intervening period. We analyze what literature has had the most influence on the field in the last decade, as indicated by citationsmade by articles published in *Ecological Economics (EE)*, and which publications in the journal have had the most influence both on the field and on the wider scientific community.We also look at the most common topics of these influential papers to find which are the most important recent topics in the field.

There are, of course, well-known issues andlimitations related to using citation analysis to assessinfluence (Costanza *et a*l., 2004), including the following:

1. The influence of a publication can go wellbeyond academia, and citation analysis will notpick up this non-academic influence.

2. Quantity of citations is not the same as quality and does not indicate whether a publication has been cited in a positive or negative way, though the vast majority of citations are positive (Catalin*et al*., 2015).

3. The databases used contain only a subset (albeit large) of articles and citations.

4. The academic review process is slow and citationanalysis is, therefore, most useful for publicationsthat are at least a few years old.

5. Similarly, influential older publications tend to be obliterated from citation counts while their influence does not diminish as their information becomes incorporated into common scientificknowledge (Merton, 1988).

6. Citation practices vary across disciplines and scientific communities, which means that comparisons across disciplines should be made carefully.

Despite these well-known limitations, citationanalysis is a powerful and increasingly popular quantitative guide to the relativeinfluence a publication has had on the academic community.Also, in this paper, we are looking at changes over time in comparison with the

results of a previous study, and so we must use similar methods to those used in the previous study.

Another important caveat regarding our analysis is the question of whether the changes we find are due to changes in the field of ecological economics or due to changes in the management of the journal, *Ecological Economics*, and the market for publications in the field. In 2004, Robert Costanza had been editor for all but one year of our sample. In the past decade, Cutler Cleveland and Richard Howarth have been the editors. The numbers of submissions and published articles have both increased strongly and the journal has become more selective. There are also more alternative outlets for publications in this field. In our analysis, we attribute the changes we see to changes in the field itself, but recognize that these other factors may also be at play.

2. Literature Review

Costanza *et al*. (2004) carried out an analysis along similar lines to the current study and found a broad range of influences on the field of ecological economics. As the field was still quite young, inward influence from classic articles in the broader environmental and economic literature were more influential on the field than were the articles actually published in *EE*. But the authors argued that this was likely to change as the field matured, as some articles published in the journal were receiving high numbers of citations per year. So, it is interesting to now follow up on that prediction.

Ma and Stern (2006) followed up Costanza *et al*.'s analysis by comparing *EE*and the *Journal of Environmental Economics and Management* (*JEEM*) in order to understand the differences between transdisciplinary ecological economics and mainstream environmental economics. They found that "there is a significant overlap between the two fields at the journal level — the two journals cite similar journals" but that "ecological economics tends to cite (but not be cited by) general natural science journals more often than environmental economics does, environmental economics cites more heavily from journals rather than other publications, and citations in environmental economics are more concentrated on particular journals and individual publications." (p491) There was much less similarity at the level of individual articles: "Non- market valuation articles dominate the most cited articles in *JEEM* while green accounting, sustainability, and the environmental Kuznets curve are all prominent topics in *EE*." (p491)We are interested in finding out whether the pattern of citation links to

the natural science literature has been sustained or not and how the topics of influential articles have evolved.

Castro e Silva and Teixeira (2011) showed how the topics covered in *EE* evolved from 1989 to 2009.They "note that ecological economics experienced an 'empirical turn' reflected in a shift away from exclusively formalized papers towards exclusively empirical and, to a larger extent, 'formal and empirical' ones"(p849). An interesting question is whether there has also been such a shift in influential papers or whether theoretical papers remain the more influential.

Hoepner *et al*. (2012) revisited the question of influential publications in environmental and ecological economics covering articles published in a group of 14 environmental and resource economics journals including *EE*in the period from 2000 to 2009. Their main indicator is citations per annum, which gives recently published papers more equal weight,and they distribute citations to authors and institutions on a fractional basis. They rank individual publications, authors,journals, and institutions with,at times, counterintuitive results. For example, Costanza ranks as the 61st most influential author.Spash (2013) criticized this analysis mainly for combining ecological and environmental economics together and thus giving a heavier weight to mainstream environmental economics, as more such journals were included. As Spash stated, Hoepner *et al*.'s(2012) research design excludes important influences on ecological economics that are outside of the economic mainstream. These are included in our study.

Plumecocq (2014) compares ecological economics research published in *EE*and *Environmental Values* with researchpublished in *JEEM* and *Environmental and Resource Economics* using textual data analysis.His results "point to the increasing importance of the evaluation of ecosystem services in ecological economic discourse". This causes him to "question the kind of transdisciplinarity promoted by ecological economics" (p458). Our results will show how the topics covered by the most cited papers in the field, including ecosystem services valuation, have evolved in the last decade.

3. Methods and Data

3.1.Identifying the influential publications

Our main analysis is based on a set of the most influential articles that we constructed as described in the following. First, we distinguish between inward and outward influence.

Inward influence occurs when publications are cited in articles published in *EE*. Outward influence occurs when articles published in *EE* are cited in other publications.

To measure inward influence, we compiled a database of all the sources cited in articles in *EE* over the 11 years,2004-2014, and selected those that received more than 15 citations in the journal in this period.We excluded institutional authors such as the IPCC and UN. We also collected the total number of citations to the identified publications in the *Web of Science*(*WoS*) as a whole and in *Google Scholar*(*GS*).We used avariety of techniques to ensure that we hada comprehensive list of publications that received more than 15 citations in the journal in the period, and that all of the citations to a publication were counted. First, we made a substantial effort to identify orphaned citations – citations to an article that should have been added to the total but were listed separately because of small variations in the recorded details of the publication. We examined all publications that have 10 or more citations and combined all orphaned citations. This gives a more comprehensive list of articles that received more than 15 citations.

We used the following approach to collect *WoS* citations.For journal articles that have correct DOIs, we used these DOIs to identify the articles and collect the associated *WoS*citations. For journal articles whose DOIs were missing or entered into the database incorrectly, we used a combination of the author's name and year of publication to identify the publication and collect its*WoS*citations.

For monographs and edited books, we followed the approach used byCostanza *et al*. (2004). The titles of monographs and edited books recorded in the *WoS*database show substantial variation. We first searched for the author's or editor's name(s) together with the publication year in order to pick up all the variations on a title in the *WoS*database. Next, we searched for all these variations of the titles without the year and the author's and editor's name(s). This yields a large list of possible references to the volume. For example, we first searched for John Rawls'*A Theory of Justice* (1971) (using "Cited Reference Search") as:

Cited Author: Rawls J*

Cited Year (s): 1971

This search identified 57 title entry variations, which we then used for the next searchusing the "Cited Work" search.[1]

We collected *WoS*and *GS*citations to journal articles between April 17 and 23, 2015.We collected *GS*citations to books on 3 May 2015and *WoS* citations to booksbetween 17 April and 19 May 2015.

Table 1. Outward Influence: Selection Criteria

Year of Publication	Total number of items	Number selected	Cutoff number of ISI citations	Cutoff number of GS citations
2004	159	15	52	n.a.
2005	197	19	59	n.a.
2006	267	26	57	n.a.
2007	347	34	56	n.a.
2008	319	31	45	n.a.
2009	311	31	39	112
2010	294	29	30	n.a.
2011	292	29	16	49
2012	243	24	11	20
2013	285	28	6	17
2014	250	23	1	5
Total	**2964**	**289**		

[1] The search terms entered in this case were: Cited Work: 'THEORY JUSTICE' OR '1971: A Theory of Justice' OR '1971: A Theory of Justice' OR '7HEORY OFJUSTICE' OR 'THEORY JUST' OR 'THEORY JUSTICE ROUTL' OR 'A THEORY OF JUSTICE' OR 'THEORY JUSTICE REV E' OR 'A theory of justice (Théorie de la justice) ' OR 'A theoryofjustice' OR 'THEORY SOCIAL JUSTIC' OR 'ATHEORY JUSTICE' OR 'J RAWLS THEORY JUSTI' OR 'THEORY JUSTICE' OR 'PREFACE THEORY JUSTI' OR 'STHEORY JUSTICE' OR 'TEORIA GIUSTIZIA' OR 'TEORY JUSTICE' OR 'THEOLY JUSTICE' OR 'THEOR JUSTICE' OR 'THEORIE GERECHTIGKEI' OR 'THEORY JSUTICE' OR 'THEORY JUCTICE' OR 'THEORY JUSETICE' OR 'THEORY JUSINCE' OR 'THEORY JUSITCE' OR 'THEORY JUSTIC' OR 'THEORY JUSTICD' OR 'THEORY JUSTICE 1' OR 'THEORY JUSTICE 90 91' OR 'THEORY JUSTICE CAMBR' OR 'THEORY JUSTICE FAIRN' OR 'THEORY JUSTICE OUP' OR 'THEORY JUSTICE OXFOR' OR 'THEORY JUSTICEE' OR 'THEORY JUSTICER' OR 'THEORY JUSTICEW' OR 'THEORY JUSTICS' OR 'THEORY JUSTICW' OR 'THEORY JUSTIDE' OR 'THEORY JUTICE' OR 'THEORY OFJUSTICE' OR 'THEORY PRACTICE' OR 'THEORY USTICE' OR 'THEORYJUSTICE' OR 'THEORYN JUSTICE' OR 'THEROY JUSITCE' OR 'THOERY JUSTICE' OR 'THOERY JUSTICT' OR 'THOEY JUSTICE' OR 'THOEYR JUSTICE' OR 'THORY JUSTICE' OR 'TREATISE JUSTICE' OR 'A Theory of Justice' OR '3HEORY JUSTICE' OR 'THEORY JUSTICE 3' OR 'THEORY JUSTICE TJ' OR 'A THEORY JUSTICE'

To measure outward influence, we examined the citations received by all articles published in the journal in the same period. We downloaded data on all the articles published in *Ecological Economics* in the designated period from *WoS* on 26 February 2015. The data include all citations included in the database up to that date. We found a total of 2960 published items for the 11 years of the sample. For the period from 1989 to 2003 there were 1364 items. We identified the most influential individual articles published in the journal based on citations in*WoS* as a whole.To deal with the varying age of articles and their corresponding variation in potential to be cited, we used the Thomson-Reuters "highly-cited" approach of picking the top fractile of most cited publications of all the publications in a given year (Thomson Reuters, 2014). Though this selects papers in recent years that havelow numbers of citations so far, Stern (2014) shows that early citations are quite strongly correlated with long-run cumulative citations and so many of these papers will turn out to be very influential. Costanza *et al*. (2004) selected 71 highly cited articles from the journal, which is about 5% of the total. We decided to extend coverage to 10% of items in each year. We also collected the number of *GS*citations to each of the identified influential articles. We collected *GS*citations to these articles on 6 March 2015. If the borderline between the top 10% and the rest of the articles fallsinside a group of articles with a common number of citations we used the number of *GS*citations received to determine the cut-off point within that group. If articles on both sides of the 10% line still have the same number of *GS*citations, we thenremoved those articles that share the same number of citations as those over the borderline. This made the most difference to the 2014 articles,which often have onlyone citation. Table 1 presents the number of articles selected in each year and the cutoff points in terms of citations used in each year.We also counted the number of citations these articles received in *EE* alone.

Table 2. Inward Influence: The Top Thirty Articles

Publication	EE cites 2004-14	EE cites 1989-2003	Total ISI cites	Total GS cites
Costanza*et al*.(1997) The value of the world's ecosystem services and natural capital, *Nature*.	139	68	5303	13350
Ostrom (1990)*Governing the Commons: The Evolution of Institutions for Collective Action*.	129	40	5939	21419
Greene (1993)*Econometric Analysis*.	107	18	14529	48504
Wackernageland Rees (1996)*Our Ecological Footprint: Reducing Human Impact on the Earth*.	94	47	1350	6239
Daily (1997) *Nature's Services: Societal Dependence On Natural Ecosystems*.	93	78	1995	5152
Georgescu-Roegen (1971)*The Entropy Law and the Economic Process*.	91	65	1454	229
Stern (2006) *Stern Review: The Economics of Climate Change*.	83	0	2222	13874
Mitchelland Carson (1989)*Using Surveys to Value Public Goods: The Contingent Valuation Method*.	81	58	2098	5929
Hardin (1968) The tragedy of the commons, *Science*.	79	30	6663	26262
Grossman and Krueger (1995) Economic growth and the environment, *Quarterly Journal of Economics*.	75	29	1087	4225
de Groot *et al*. (2002) A typology for the classification, description and valuation of ecosystem functions, goods and services, *Ecological Economics*.	72	2	786	2321
Freeman *et al*.(2003)*The Measurement of Environmental and Resource Values*.	70	30	986	3588
Miller and Blair (2009) *Input-Output Analysis: Foundations and Extensions*.	63	0	1213	4203
Arrow *et al*.(1993) Report of the NOAA panel on contingent valuation, *Federal Register*.	60	19	1000	53
Train (2003) D*iscrete Choice Methods with Simulation*.	60	0	2672	7832

Daly and Cobb (1989)*For the Common Good*.	59	96	904	4923
Meadows *et al*.(1972)*The Limits to Growth*.	59	26	4592	13013
Louviere *et al*. (2000)*Stated Choice Methods: Analysis and Application*.	59	0	1702	4461
Coase(1960) The problem of social cost, *Journal of Law and Economics*.	57	26	4636	25204
Daly (1973) *Toward a Steady State Economy*.	55	49	309	1417
McFadden (1974) Conditional logit analysis of qualitative choice behaviour,in: *Frontiers in Econometrics*.	54	10	2829	152
Engel *et al*. (2008) Designing payments for environmental services in theory and practice: An overview of the issues, *Ecological Economics*.	53	0	435	1049
Porter(1995) Toward a new conception of the environment-competitiveness relationship, *Journal of Economic Perspectives*.	52	20	1178	4560
Stern (2004) The rise and fall of the environmental Kuznets curve, *World Development*.	51	0	478	1365
Selden and Song(1994) Environmental quality and development: Is there a Kuznets Curve for air pollution emissions?*Journal of Environmental Economics and Management*.	49	31	585	2024
Dalyand Farley (2004) *Ecological Economics: Principles and Applications*.	48	0	213	1303
North (1990) *Institutions, Institutional Change and Economic Performance*.	48	15	8919	35345
Leontief (1970) Environmental repercussions and the economic structure: An input-output approach, *Review of Economics and Statistics*.	47	15	553	1459
Wunder (2005)*Payments for Environmental Services: Some Nuts and Bolts*.	44	0	310	1208
Norgaard (1994)*Development Betrayed: The End of Progress*.	42	32	414	1524

Table 3. Outward Influence: Top Three Articles by Year

Article	ISI Citations	GS Citations	EE Citations
Dinda (2004) Environmental Kuznets Curve hypothesis: A survey	311	1156	33
Robinson (2004) Squaring the circle? Some thoughts on the idea of sustainable development	170	713	11
Adhikari*et al*. (2004) Household characteristics and forest dependency: evidence from common property forest management in Nepal	109	326	16
Pimentel *et al*. (2005) Update on the environmental and economic costs associated with alien-invasive species in the United States	1113	1992	27
Jaffe *et al*. (2005) A tale of two market failures: Technology and environmental policy	196	668	10
Max-Neef (2005) Foundations of transdisciplinarity	124	477	9
Hein *et al*. (2006) Spatial scales, stakeholders and the valuation of ecosystem services	239	626	23
Chapagain*et al*. (2006) The water footprint of cotton consumption: An assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries	146	406	10
Troy and Wilson (2006) Mapping ecosystem services: Practical challenges and opportunities in linking GIS and value transfer	135	322	16
Boyd and Banzhaf (2007) What are ecosystem services? The need for standardized environmental accounting units	330	921	35
Wiedmann*et al*. (2007) Examining the global environmental impact of regional consumption activities - Part 2: Review of input-output models for the assessment of environmental impacts embodied in trade	253	377	42
Zhang *et al*. (2007) Ecosystem services and dis-services to agriculture	184	452	11
Engel *et al*. (2008) Designing payments for environmental services in theory and practice: An overview of the issues	377	1017	53
Wunder*et al*. (2008) Taking stock: A comparative analysis of payments for environmental services programs in developed and developing countries	233	640	36
Peters (2008) From production-based to consumption-based national emission inventories	172	394	30

Fisher *et al*. (2009) Defining and classifying ecosystem services for decision making	331	946	27
Gallai*et al*. (2009) Economic valuation of the vulnerability of world agriculture confronted with pollinator decline	268	659	7
Zhang and Cheng (2009) Energy consumption, carbon emissions, and economic growth in China	134	360	2
Norgaard (2010) Ecosystem services: From eye-opening metaphor to complexity blinder	156	373	27
Muradian*et al*. (2010) Reconciling theory and practice: An alternative conceptual framework for understanding payments for environmental services	140	390	36
Gomez-Baggethun*et al*. (2010) The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes	130	410	19
Kallis (2011) In defence of degrowth	55	174	11
Wiedmann*et al*. (2011) Quo Vadis MRIO? Methodological, data and institutional requirements for multi-region input-output analysis	52	109	7
Chapagain and Hoekstra (2011) The blue, green and grey water footprint of rice from production and consumption perspectives	48	92	1
Chan *et al*. (2012) Rethinking ecosystem services to better address and navigate cultural values	71	189	15
Jahn*et al*. (2012) Transdisciplinarity: Between mainstreaming and marginalization	39	96	2
Horbach*et al*. (2012) Determinants of eco-innovations by type of environmental impact - The role of regulatory push/pull, technology push and market pull	28	151	4
Gomez-Baggethun and Barton (2013) Classifying and valuing ecosystem services for urban planning	32	87	1
Kubiszewski*et al.* (2013) Beyond GDP: Measuring and achieving global genuine progress	20	74	0
Jax*et al*. (2013) Ecosystem services and ethics	17	35	2
Zhang and Anadon (2014) A multi-regional input-output analysis of domestic virtual water trade and provincial water footprint in China	8	18	0
Jobstvogt*et al*. (2014) Twenty thousand sterling under the sea: Estimating the value of protecting deep-sea biodiversity	7	20	1
Abson*et al*. (2014) Ecosystem services as a boundary object for sustainability	4	12	0

3.2.Identifying the influential themes

Weidentifiedthe importance of the various subject themes of the most inwardly and outwardly influential publicationsby attaching a theme to each of the 679 most influential publicationsthat we identified.After eliminating duplicate publications that appear both in the inward and in the outward influencelists, we obtained635unique influential publications. These publications arethen clustered following a descending hierarchical classification method (Reinert, 1983) applied to the vocabularyused in the titles of these publications. This clustering techniqueproceeds from a contingency table that enables us to count the presence or absence of words in a given title.All the words found in the titles (except pronouns, conjunctions, and some adjectives)are placedin rows; the 635 uniquepublicationsare placedin the columns. The hierarchical descending classification commencesby splitting the ensemble of columns into two contrastinggroups in terms of the presence or absence of the occurrence of words.These two clusters then contain mutually exclusive vocabularyso that words present in one cluster are relatively absent in the other one, and *vice versa*.We test whether there is a significant difference in the relative abundance of a word inside and outside the clusterusing a chi-square test evaluated at the 5% significance level.The classification then proceeds via an iterative process: the largestof the two clustersin terms of number of publicationsis divided into two contrasting groups; then amongst these three clusters, the largest is again divided; etc.The iterative process stops either when the number of clusters predefined by the analyst is reached, or when no significantly different vocabularycan be found in the largest cluster.We repeated this iterative process by progressively increasingthe number of clusters requested so as to get the finestpossible clustering. In our case, we obtained 53 clusters. We labeled these clusters according to their main theme words (based on chi-square values), and proceeded to reallocatepublicationsthat were misplaced and to amalgamateclusters that arevery close in theme.[2]

Using this algorithm, we obtained 22 clusters (i.e. 22 themes). Only 5 publications remainedunclustered. Table 2 presents the full list of 22 clusters (themes) and some statistics.

[2] Two types of misclassification were found. First, some clusters were formed on the basis of artifacts. For instance, publications using the word “question”, and no other word significantly associated to other classes were clustered together, although they really belonged to very different themes. Second, some clusters might attract publications containing only one of a group of words, which characterized the cluster. For example, some publications mentioning “analysis” might be grouped with those mentioning “input-output analysis”. These publications were regrouped.

Table 4. Themes: Number of Publications and Citations by theme

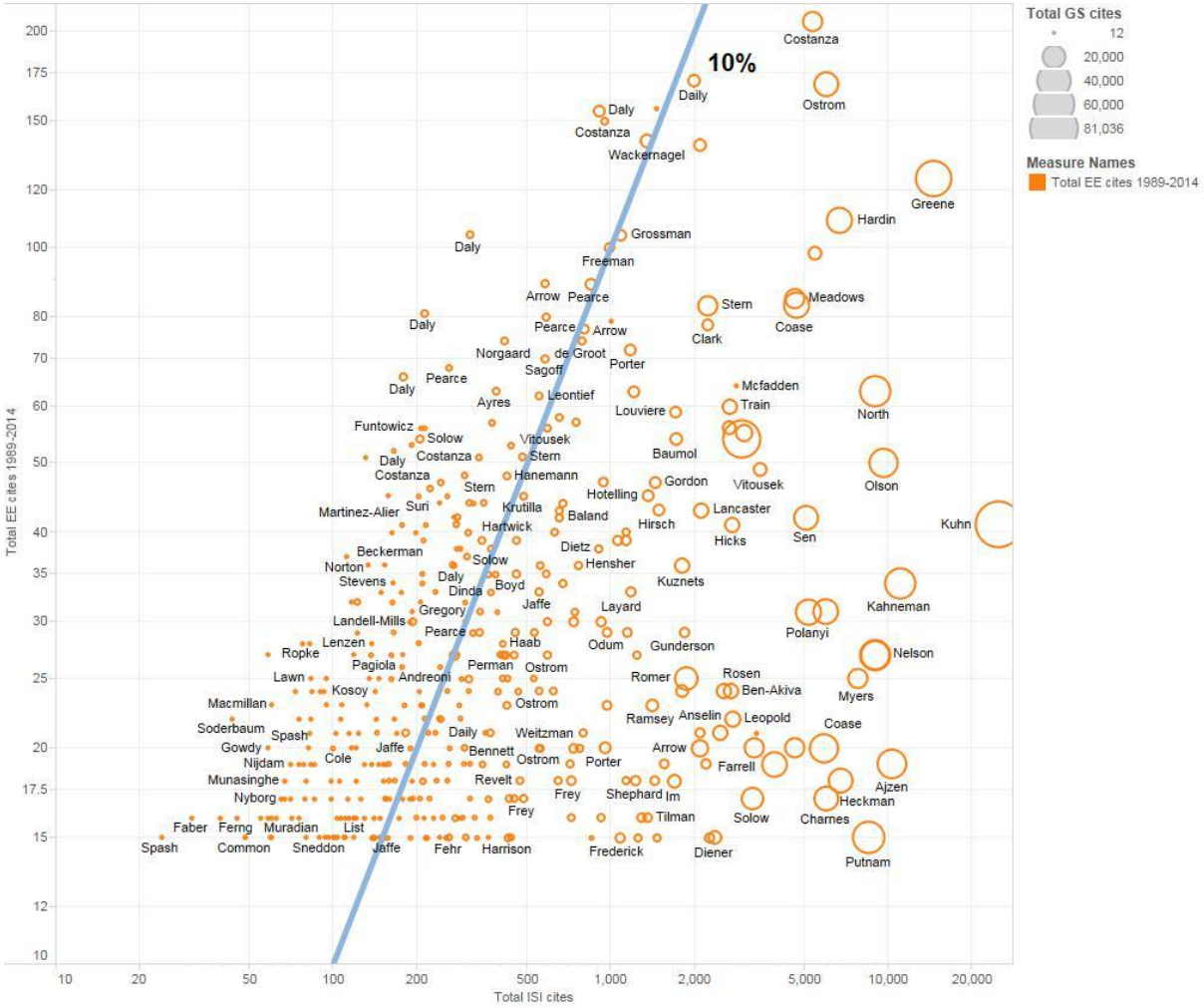
Theme	Number of Inward Publications	Number of Outward Publications	Total Publications (eliminating double counting)	Share in Total Publications	Inward Citations	Outward Citations	Total Citations (eliminating double counting)	Share in Total Citations
Social aspects (behaviors and institutions)	33	20	50	7.9%	776	1002	1725	6.3%
Valuation	35	16	49	7.7%	935	1011	1912	6.9%
Environmental policy and	23	25	46	7.2%	659	831	1459	5.3%
Technical change	17	26	43	6.8%	345	1419	1764	6.4%
Ecological economics	24	15	37	5.8%	547	773	1277	4.6%
Happiness and poverty	27	11	37	5.8%	600	627	1210	4.4%
Impacts assessment	18	21	37	5.8%	388	1349	1701	6.2%
Economy and the environment	28	10	36	5.7%	715	452	1119	4.1%
Payment for ecosystem services/conservation	19	26	33	5.2%	484	2356	2519	9.1%
Ecosystem services valuation	19	12	28	4.4%	526	1887	2346	8.5%
Ecosystem services categorization/application	9	23	27	4.3%	252	1881	2009	7.3%
Flow-stock models/Energy analysis/Metabolism	11	16	26	4.1%	268	1095	1347	4.9%
Sustainable development	9	20	26	4.1%	189	1228	1350	4.9%
Conservation, ecosystems, biodiversity, species	15	8	23	3.6%	385	423	808	2.9%
Input-Output analysis	12	12	21	3.3%	349	871	1129	4.1%
Ecological footprint	16	5	20	3.1%	446	247	669	2.4%
Environmental Kuznets curve	18	3	20	3.1%	450	470	887	3.2%
Statistics/Econometrics	18	0	18	2.8%	544	0	544	2.0%
Environmental/neoclassical economics	16	1	17	2.7%	381	13	394	1.4%
Limits to growth, steady state, and de-growth	12	5	16	2.5%	349	177	509	1.8%
Epistemology/interdisciplinary	6	5	11	1.7%	154	325	479	1.7%
Land use	3	6	9	1.4%	53	257	310	1.1%
Varied	2	3	5	0.8%	34	58	92	0.3%
Total	**390**	**289**	**635**	**100.0%**	**9829**	**18752**	**27559**	**100.0%**

3.3.Journal level data

In addition to this main analysis, werepeatthe analysis of Ma and Stern (2006) on which journals are most cited by *EE* and which journals cite *EE*most using data from the *Journal Citations Report*for the period 2004 to 2014.

Figure 1. Inward Influence: Publications Highly Cited by *EE* Articles.

The figure is a log-log plot of total *WoS* citations vs. *EE* citations. Circle size indicates the number of *GS* citations.



4. Results

4.1. Inward influence

Table 2lists details of the top 30 publications,regardless of when they were published, ranked by number of *EE* cites in the 2004-14 period. Figure 1 is a log-log plot of the number of *WoS* cites vs. the number of *EE* cites for all the articles we included in our survey of inward influence, along with an indication of the number of *GS* cites by the size of the circles. It also

shows the line where the number of *EE* cites is 1/10 of the number of *WoS* cites. Publications to the right of this line are 10 times or more cited in *WoS* relative to in *EE*.

One striking difference between Figure 1 and Figure 2, which presents outward citations,is the relative lack of correlation between *WoS* and *EE* cites in Figure 1 compared to Figure 2. There are many articles in Figure 1 with very high *WoS* cites but relatively low *EE* cites. These are publications such as Kuhn's (1962) book *The Structure of Scientific Revolutions* that are very highly cited in general but have had only a moderate influence on *EE*.

Costanza *et al*. (1997)was the most highly cited publication in *EE* in the 2004-14 period, and the second highest in the 1989-2003 period after Daily (1997), an edited book.Both these publications are on the topic of ecosystem services. It is also notable how many of the top items are books (including Ostrom (1990), Daily (1997), Stern (2006), etc.). This is not surprising, since books in general garner higher overall citations than journal articles (LSE Public Policy Group, 2011). Only two articles published in *EE* appear in this top thirty list - de Groot *et al*. (2002) and Engel *et al*. (2008) – both of which are also on the topic of ecosystem services.

Figure 3 is a log-log plot of the relationship between *EE* citations in the 1989-2003 period vs. *EE* citations in the 2004-2014 period to show which articles have had continuing influence on *EE* citations. This plot, of course, only includes articles published before 2003. Most of these publications have continued to have ongoing influence. A few exceptions that have had waning influence with relatively fewer citations in the later period include Hanemann (1991), Pearce*et al*. (1989), and Costanza (1991), all "foundational" books.

The most inwardly influential publications in the 1989-2003 period dealt with the themes of ecological economics (15.6%), and conservation, ecosystems, biodiversity, and species (11.7%). Altogether these two themes represent only 9.5% of the citations in the second period. Instead the themes that became influential are valuation (9.5%), social aspects of environmental issues, including behavioral and institutional dimensions (7.9%), and the exploration of the relationships between the economy and the environment (7.3%).

Figure 2. Outward Influence: Highly Cited Papers Published in *EE*from 2004 to 2014

The chart plots total *WoS* citations vs. *EE* citations. Size of the circle is number of *GS* citations. Darkness of color indicates publication year.

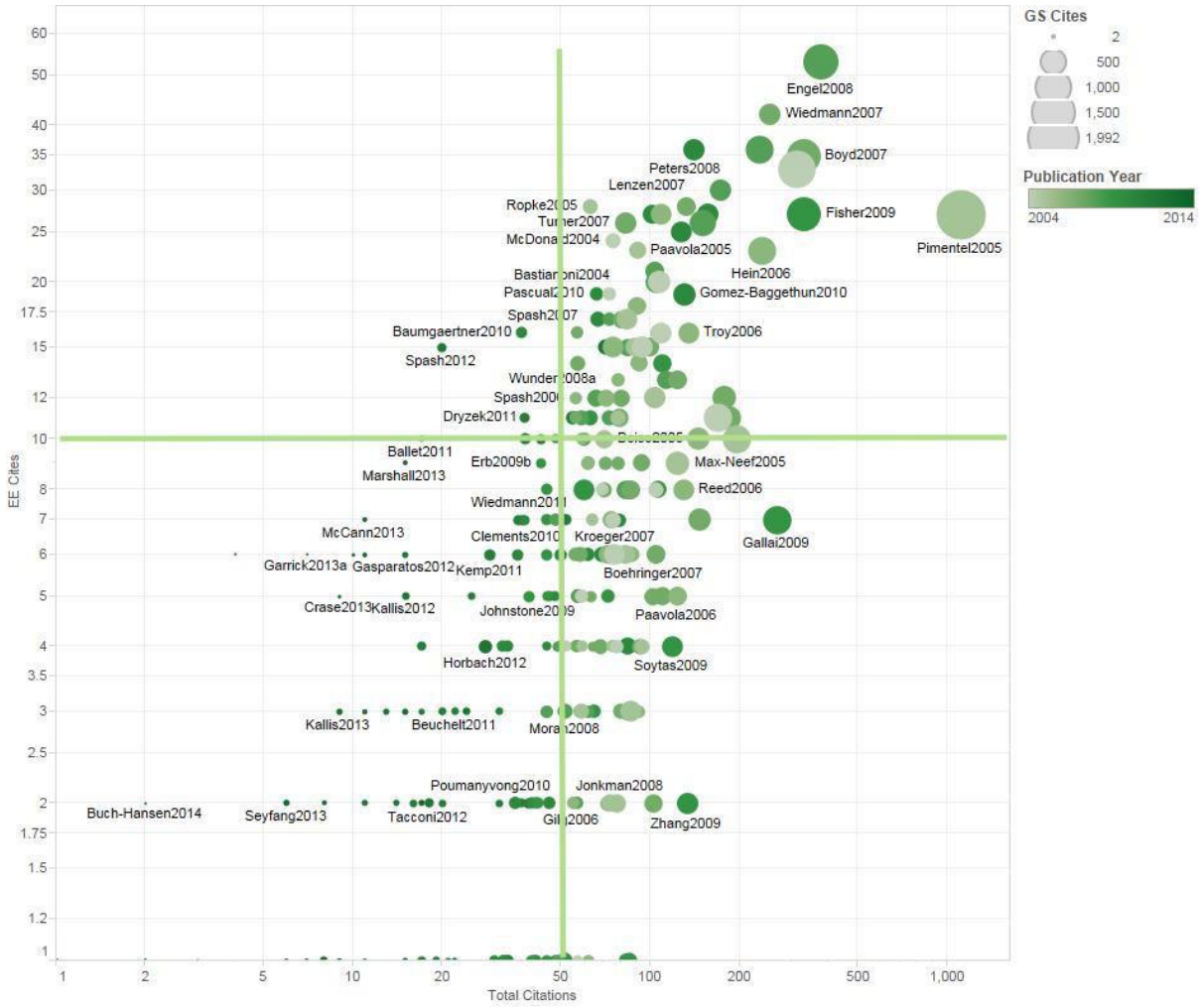
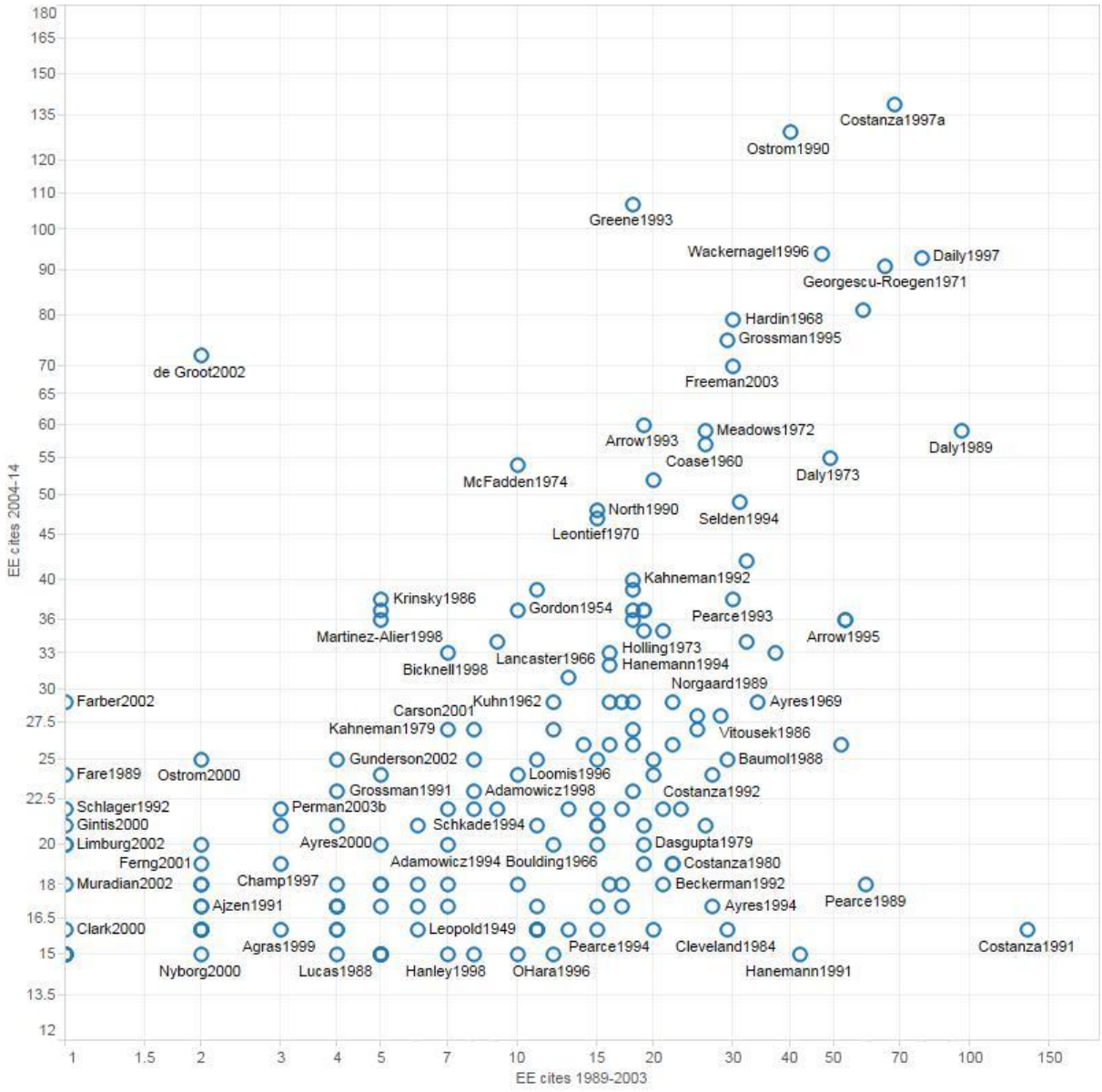


Figure 3. Changes in Inward Influence: Relationship between *EE* Citations Received from 1989 to 2003 and*EE* Citations Received from 2004 to 2014.



4.2. Outward influence

Table 3 lists the top three articles published in *EE* ranked by *WoS* citations in each of the years 2004 to 2014 and their *EE*, *WoS*, and *GS* citations.Figure 2 is a plot of the outward influence of the most highly cited papers published in *EE* in the 2004-2014 period.The chart shows total *WoS* citations on the x-axis vs. total *EE* citations on the y-axis, with the size of the circles indicating the number of *GS* citations and the color of the circles indicating the year of publication. The most highly cited article published in *EE*across the eleven years in both *WoS* and *GS*is Pimentel *et al*.'s (2005) article on the economic costs of invasive species. This article also has the highest average citations per year. However, it is not the most cited

article in *Ecological Economics*. That is Engel *et al*.'s (2008) article on designing environmental service payments (PES). This shows a divergence between outward and inward influence that will be explored further below. Many of the most inwardly influential papersin this group (i.e. papers that were both highly cited in *EE* and highly cited in general) are on PES. Engel *et al*.'s paper is also the second most outwardly influential paperin terms of citations per year. 14 of the 33 top articles ranked by *EE* citations contain both the terms"ecosystem" and"service" or "environmental"and "service" in their title and others appear to be on related themes, indicating the importance of this theme in *EE* in this period.We also observe a fairly strong correlation between *EE* cites and *WoS* cites for these papers, indicating that highly cited papers in *EE* are also highly cited elsewhere, with an average ratio of about 5 *WoS* cites for every 1 *EE* cite.This indicates the broader influence of papers published in *EE*beyond the journal itself.This may also be because in the last 10 years the accessibility of journal articles has increased dramatically and where a paper is published now has less influence on who reads it and cites it.It could also indicate that more influential authors are now deciding to publish in EE.

How have things changed since Costanza *et al*. (2004)? First, some of the articles in Table 3and Figure 2 have very substantial*WoS*citations, which was not the case for articles published in the journal prior to 2004. Pearce and Atkinson (1993) was the article that had received the most *WoS*citations at that point – a total of 75. Second, the most popular topics among the top articles prior to 2004 were sustainable development and mainstream environmental valuation methods as well as a number of papers on the foundations of ecological economics (receiving 16.8% and 16.7%, respectively, of the citations of the influential articles in the first period). These themes have changed dramatically, as shown in Table 4.In the 2004-2014 period,the influential papers published in *EE*on the three themes related to ecosystem services (payment for, valuation, and categorization)received the largest number of citations (12.6%, 10.1%, and 10%, respectively,32.7% altogether), while sustainable development and ecological economics decreased in importance and received only6.5% and 4.1% of the citations to influential articles, respectively.

4.3. Influential themes

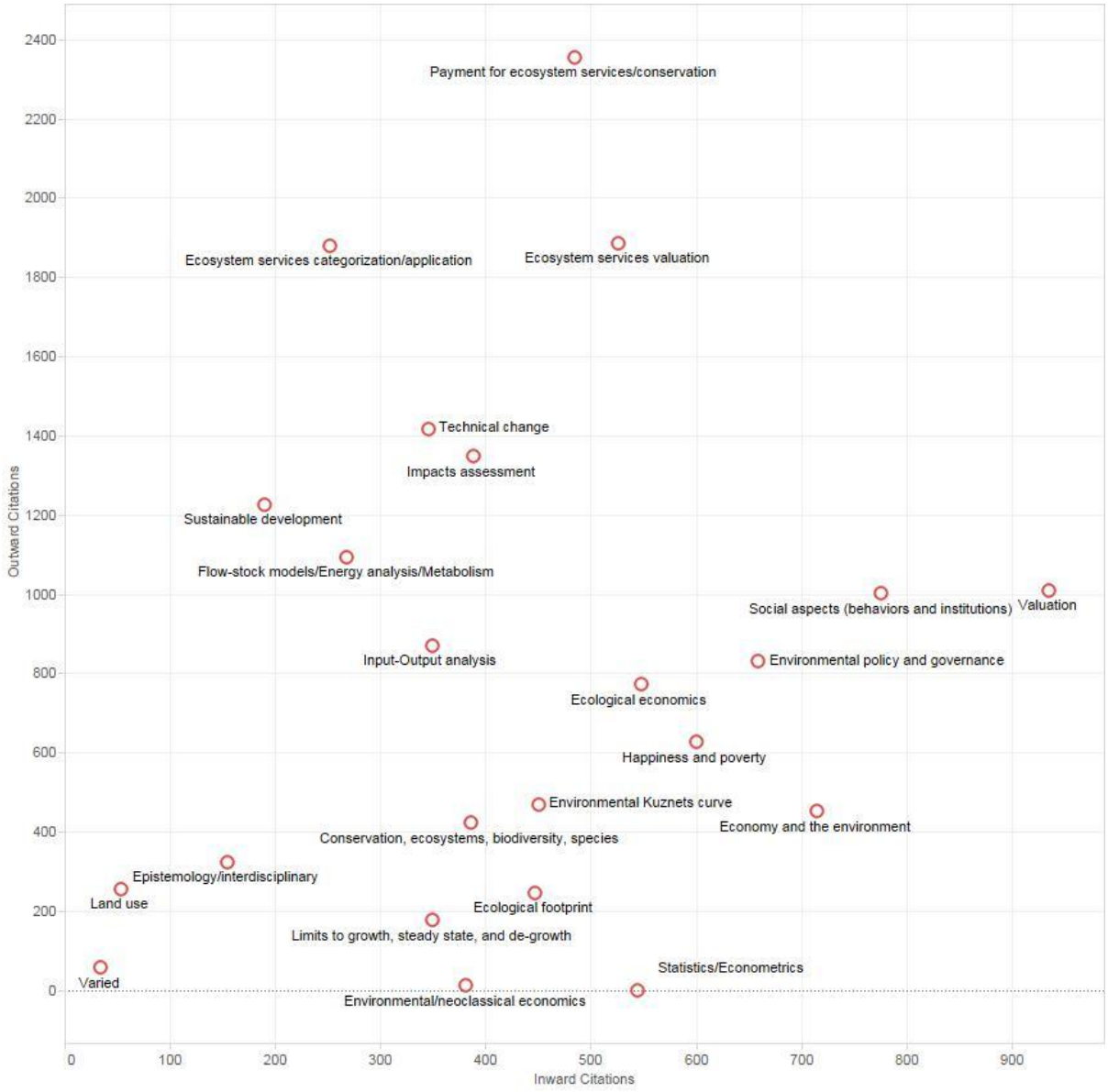
Table 4 shows the results of the thematic clustering procedure. The largest cluster - on the theme of "behaviors and institutions" - contains 50publications, closely followed by 49 publications on "valuation."The smallest cluster- on the theme of "land use" - contains 9

publications. However, if we aggregate the three themes relatedto ecosystem services (payment for, biodiversity, and categorization) their total number of publications is 85, indicating the prevalence of this topic. In terms of citations, these three themes together had 25% of the total citations (an average of 78 citations per paper for these themes, compared to 43.4 citations on average for all identified influential publications), with the next largest cluster – "valuation" – having only 6.9% of total citations.

The number of applied themes does suggest that there has been a move away from the dominance of the more foundational themes. However, it is hard to determine from the theme analysis whether *EE* has produced more influential applied papers in the last decade than previously. Wemight expect theoretical or review papers to be more influential in *EE*.[3]Looking at the top outward influential papers, we find theoretical or conceptual ones: Boyd and Banzhaf (2007) andFisher *et al.* (2009)provide classifications of ecosystem services, Engel *et al.*(2008) is an overview of concepts and issues in PES,Dinda (2004) is a survey of the environmental Kuznets curve,and Wiedmann*et al.* (2007) a review of input-output models. But,somewhat unexpectedly, other influential papers are more applied: Pimentel *et al.* (2005) study the economic cost of invasive species, Gallaï*et al.* (2009) calculate the value of pollination services, and Wunder*et al.* (2008) compare two PES schemes. While these studies are applied, their results and outcomes are very general so that they can easily be mobilized in other research to provide overview data that helps in framing more specific issues. Nevertheless, an analysis of the co-occurrence of the words contained in the titles suggests that the growing influence of (payments for) ecosystem services is coupled with an empirical trend. When splitting the timeframe into two periods, we can even distinguish two phases of this evolution: under the editorship of Cutler Cleveland, 9% of the influential publications associated the terms "theory" and "practice" in their titles; and 9% of the influential papers published under the editorship of Richard Howarth (from 2008) contained both the words "case" and "study" (ranked as the fifth most frequent association of words in the titles of articles published since 2008). It also seems that the emergence and influence in the last decade of themes such as PES or more broadly ecosystem services has led to more applied papers, especially under Richard Howarth's editorship (Table 3).

[3]In science as a whole, methods papers tend to receive the most citations (van Noorden*et al*., 2014) and reviews receive lower citations than original research in biomedicine (Lokker *et al*., 2009).

Figure 4. Inwardly and Outwardly Influential Themes



4.4 Journal level analysis

Table 5 uses data from the *Journal Citation Reports* to list the 20 journals that most frequently cited *EE* and were most frequently cited by *EE* in the years 2004-2014. As noted by Ma and Stern (2006), *EE* cites the general science journals *PNAS*, *Science*,and *Nature* but is obviously cited by those journals much less. There is also a tendency to cite the mainstream environmental and resource economics journals *Environmental and Resource Economics*, *JEEM*, *Land Economics*, and *American Journal of Agricultural Economics* but to be much less cited by them. However, this less pronounced than in 2003 when those four journals were the four most cited in *EE* after the journal itself. Instead interdisciplinary environmental studies journals such as *Global Environmental Change*, *J. Environmental*

Management, *Ecology and Society*, and *Environmental Science and Technology* are much more prominent. No core economics journal now appears in the top 20, whereas in 2003 the *American Economic Review*, *J. Political Economy*, and *Quarterly Journal of Economics* all featured. *Energy Policy* now is the second most cited journal and *Energy Economics* also features in the top 20 list, reflecting the expansion of publication in energy economics and policy in recent years. There has also been a reduction in the prominence of economics journals in the list of the top 20 journals citing *EE* and a rise in interdisciplinary environmental studies and energy journals as well as interdisciplinary mega-journal *PLOS One*.

Table 5. Most Cited and Most Citing Journals 2004-2014

Top 20 journals citing EE 2004-14		**Top 20 journals cited by EE 2004-14**	
Journal	**Citations**	**Journal**	**Citations**
ECOL ECON	936	**ECOL ECON**	920
ECOL INDIC	322	**ENERG POLICY**	165
J CLEAN PROD	264	P NATL ACAD SCI USA	143
SUSTAINABILITY-BASEL	231	**ENVIRON RESOUR ECON**	109
ENERG POLICY	221	GLOBAL ENVIRON CHANG	92
LAND USE POLICY	178	**SCIENCE**	90
GLOBAL ENVIRON CHANG	153	**J ENVIRON MANAGE**	66
PLOS ONE	142	ECOL SOC	63
RENEW SUST ENERG REV	140	ENVIRON SCI TECHNOL	63
J ENVIRON MANAGE	137	**J ENVIRON ECON MANAG**	62
ECOL SOC	127	**LAND ECON**	57
ENERG ECON	124	LAND USE POLICY	57
ENERGY	112	ENERG ECON	56
ENVIRON SCI TECHNOL	100	**NATURE**	52
SCI TOTAL ENVIRON	96	**WORLD DEV**	51
ENVIRON MANAGE	90	BIOL CONSERV	45
FOREST POLICY ECON	81	**AM J AGR ECON**	43
ENVIRON RESOUR ECON	71	**CONSERV BIOL**	42
MAR POLICY	69	ECOL INDIC	42
APPL ENERG	66	ECON SYST RES	38

Journals marked in bold are common to the lists in Ma and Stern (2006)

5. Discussion and Conclusions

We have described and analyzed the publications in the broader literature that have influenced *EE*(inward influence) based on their citation rates in *EE*, and the influence of articles published in *EE*(outward influence) based on citation rates in both the journal itself and the broader literature (*WoS* and *GS*). We have also described how these citations have

changed over time and how the citation rates of major themes covered in *EE*have changed over time.These patterns are complex, but we can draw a few conclusions.

EE is a unique, transdisciplinary, journal that cites and is cited by a broad range of other sources. In its first 14 years (1989-2003) it was building its reputation and the inward influence in citations was much larger than its outward influence.This has changed to some degree in the 2004-2014 period.As Figure 1 shows, papers published in *EE*now average 5 citations in *WoS* for every one in *EE*, and some have garnered hundreds of *WoS* citations.

As for inward influence, publications in *EE* often cite publications from general interdisciplinary natural science journals and books, again a testament to its transdisciplinary nature. Citations to economics journals whether environmental and resource economics journals or core economics journals have declined and environmental and resource economics journals have also dropped down the citing journal list, as shown in Table 5. Interdisciplinary environmental studies journals increasingly dominate both the cited and citing journal lists.

Of course, we cannot answer all questions about a journal's influence and themes from citation analysis, which only charts influence in the academic literature and is subject to other limitations as noted previously.There are certainly many other interesting questions to address concerning, for example, how opinions have evolved over time on particular topicslike ecosystem services, PES, and environmental Kuznets curves. These have been examined to some degree in previous research (e.g. Plumecocq, 2014).

EE is now 26 years old.Its themes and publication patterns have changed dramatically over that period, but it has retained its commitment over three editors, to being a unique venue for research that transcends disciplinary boundaries.The world itself has also changed dramatically over the life of the journal, in part because of the work of ecological economists themselves and by many others who have been influenced by them, to one in which the topics covered in *EE* have become even more important to the future of humanity.We hope that the analysis of past patterns of publication in this paper can help future editors and authors to develop priorities for the future.

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